



# Can Wing Tip Vortices Be Accurately Simulated?

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JULY 2011

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# **Can Wing Tip Vortices Be Accurately Simulated?**

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**<sup>a</sup>Science and Teacher Researcher (STAR) Program, Cal Poly San Luis Obispo**

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## Wingtip Vortices and the Rationale of This Project

Wingtip vortices are the result of a pressure difference between the top and bottom of an aircraft wing or helicopter rotor moving through air. In military applications, wing tip vortices have adverse effects on towed vehicles and cause additional tail buffeting.<sup>2</sup> In commercial applications, winglets have been installed on passenger aircraft to minimize vortex formation and reduce lift-induced drag.<sup>2</sup>

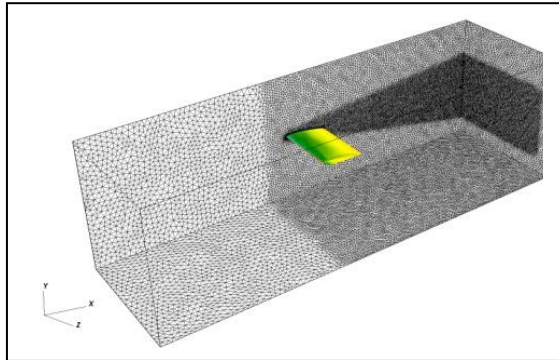
Visually, wingtip vortices can be thought of as a horizontal tornado (as shown in Figure 1), whose cross-sectional area increases with increasing downstream distance.

From a computational standpoint, modeling wingtip vortices has been a challenging area of study. It has only been in recent years that computational tools that better resolve and approximate wingtip vortices have been developed. This project sought to expand on gains made by using incrementally more computationally intensive simulations. Determination of the accuracy of the model wingtip vortices was accomplished by comparing simulation results to experimental data.

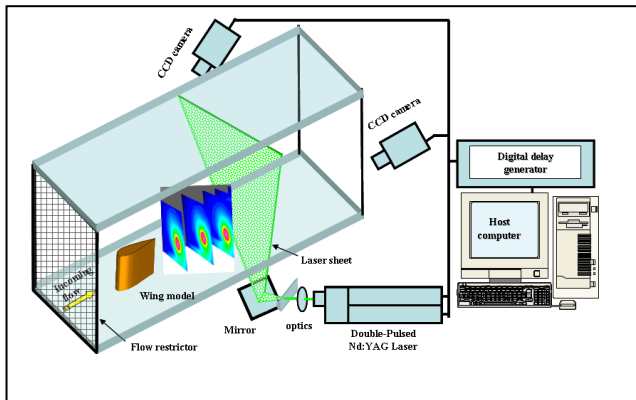
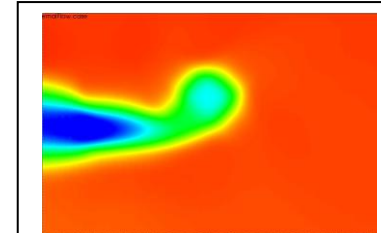
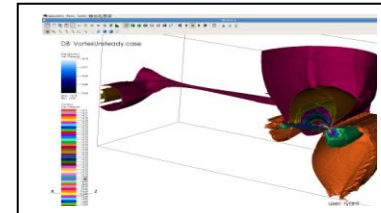


**Figure 1 – Visual Representation of Wingtip Vortices**

## Methods

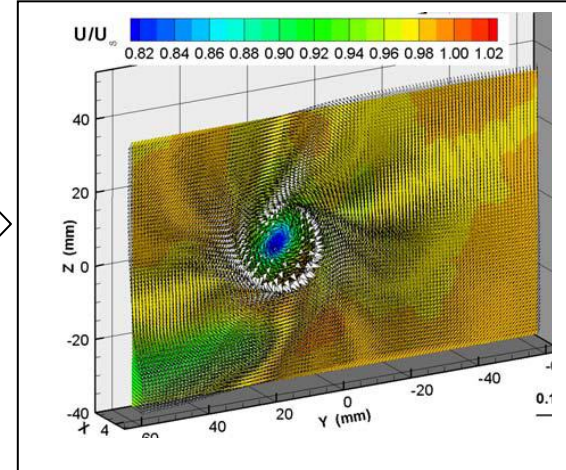


Numerical results of  
simulations sent to  
visualization program  
*VisIt*

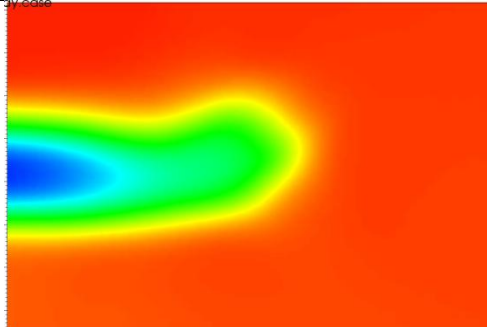
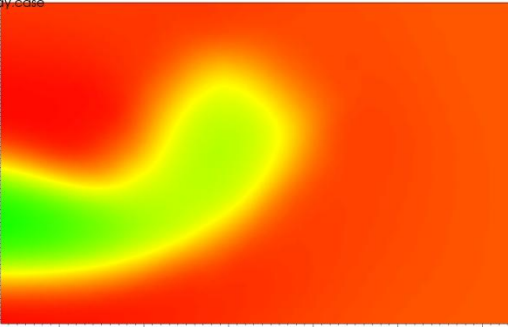
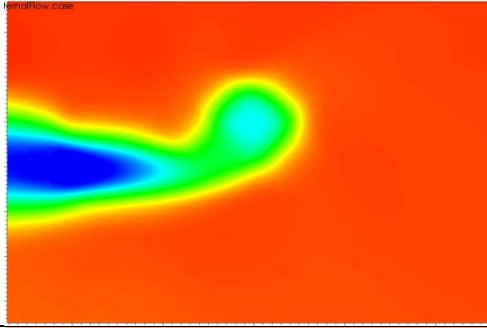
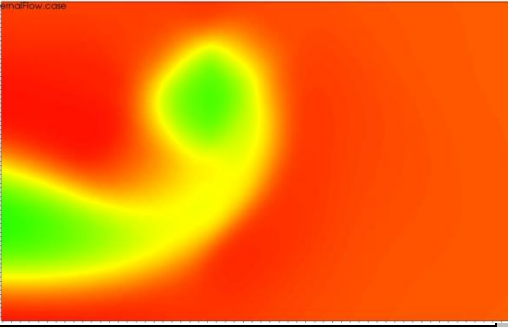
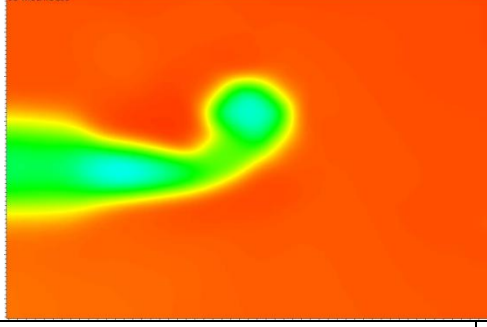
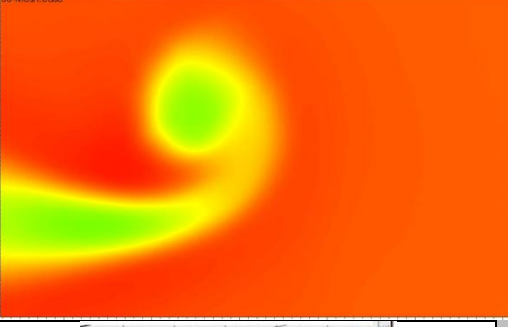
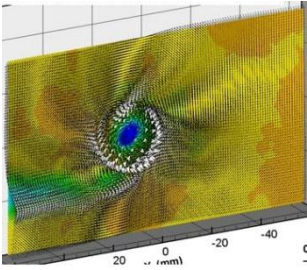
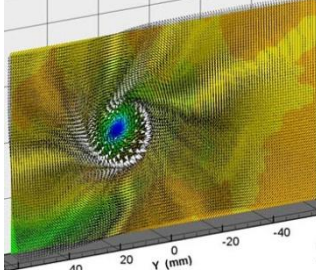


**Figure 2 – Experimental Setup using  
StereoScopic Particle Image Velocimetry  
(SPIV) (Ref 2)**

Data from Iowa State  
University wind tunnel  
experiment compared  
to simulation.



Ref 2

| Plots of Instantaneous Velocity over Freestream Velocity and Equivalent SPIV Images |  |   |  |
|---|--|---|--|
| Simulation  | 4" downstream of trailing edge   | 16" downstream of trailing edge   | Legends  |
| Sim0<br><br>Sim3<br><br>Sim7  |                       |                       | <div>Simulation</div> <div> <div>Pseudocolor</div> <div>Var: UoverU_inf</div> <div> <div>1.020</div> <div>0.9700</div> <div>0.9200</div> <div>0.8700</div> <div>0.8200</div> </div> <div>Max: 1.201</div> <div>Min: -0.6317</div> </div> |
|   |                       |                       |  |
|   |                      |                      |  |
| SPIV <sup>2</sup>   |  <div>(Ref 2)</div> |  <div>(Ref 2)</div> |  |

## Approximate Size and Location of Vortex Cores

From the 2D data collected, the vortex cores were approximated to be ellipses, and size and location were found and plotted for 4", 8", 12", 16" downstream of TE.

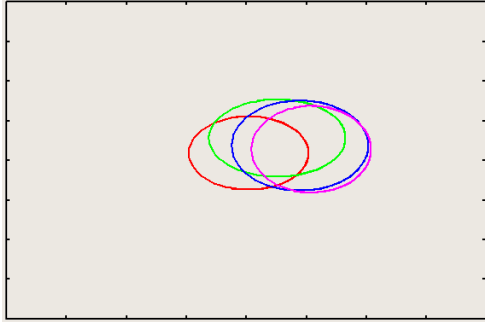
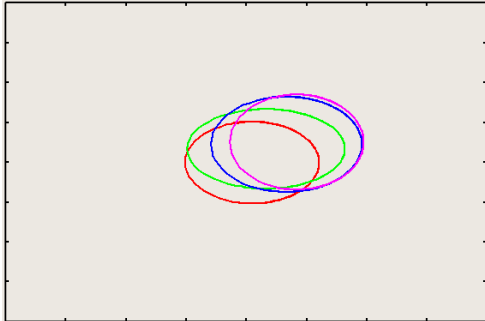
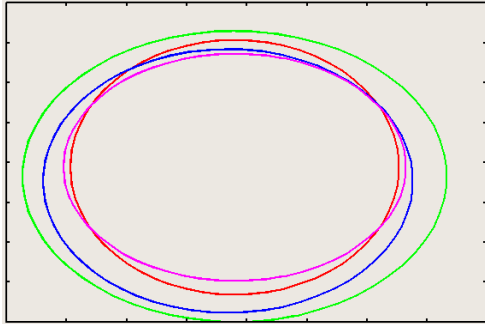
### Legend

Purple = 4" downstream

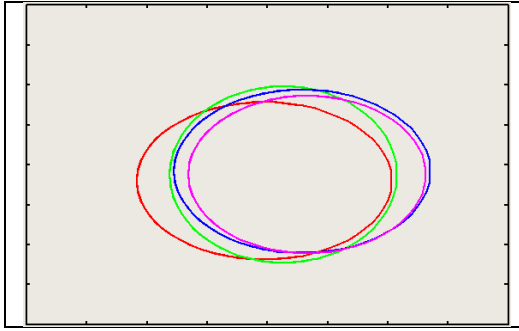
Blue = 8" downstream

Green = 12" downstream

Red = 16" downstream







## Discussion

### Instantaneous Velocity over Freestream Velocity with Equivalent SPIV Images

- All three simulations and SPIV show a counterclockwise “curl” forming downstream of the right edge of the wing and from the color scale confirms an expected inverse relationship between vortex velocity and distance from the center (Ref 1).
- The shapes of Sim3 and Sim7 more closely resemble that of SPIV for both downstream locations.
- Sim7 shows more detail than Sim3 and is most like the SPIV plots, as at the 16” mark the plot clearly shows a defined vortex core separated from the horizontal “wash” of the wing.

### Vortex Core Size and Location Approximation

As downstream distance from the trailing edge increases:

- Sim0 only shows increase in vortex core area with no core displacement
- Sim3 shows increasing change in area and a core displacement up and to the left.
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## Conclusion

- Simulated wingtip vortex development and behavior more closely resembles that of SPIV for finer and denser mesh sizes. The same can be said for vortex core area, and thus the size of the vortices can be approximated by future simulations using a mesh size at least that of Sim7.
- Future work for the simulations need more accurately measured dimensions and coordinates of vortices in the 2D plane, as well as have more exact data from the SPIV experiments. With more accurate measurements there is a need to numerically verify the error of the simulations in comparison to SPIV data to make a better judgment about whether the simulations are reliable to use.
- If the simulations for wingtip vortices are reliable, they can be used to make more efficient use of wind tunnel tests and aid in the design process of aircraft.

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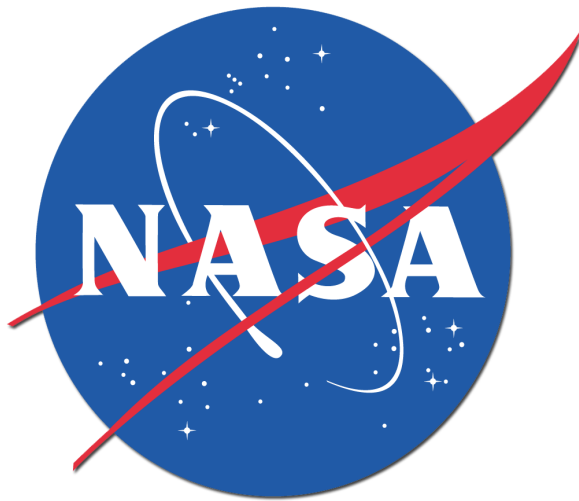
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- Ref 3: Stewart, R. (2002, October 2). *Wake Turbulence Commentary*. Retrieved July 16, 2011, from Robyn's Flying Start: <http://www.flyingstart.ca/FlightTraining/PSTAR/7As.htm>



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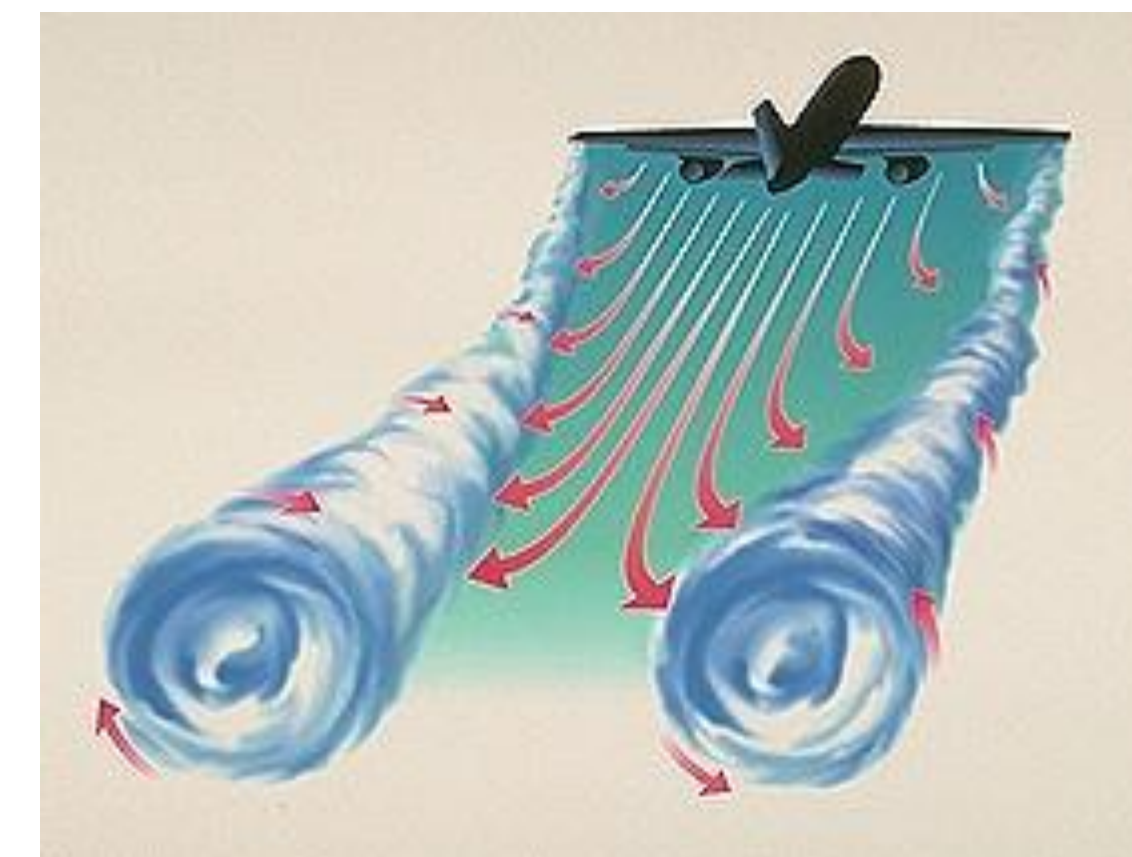
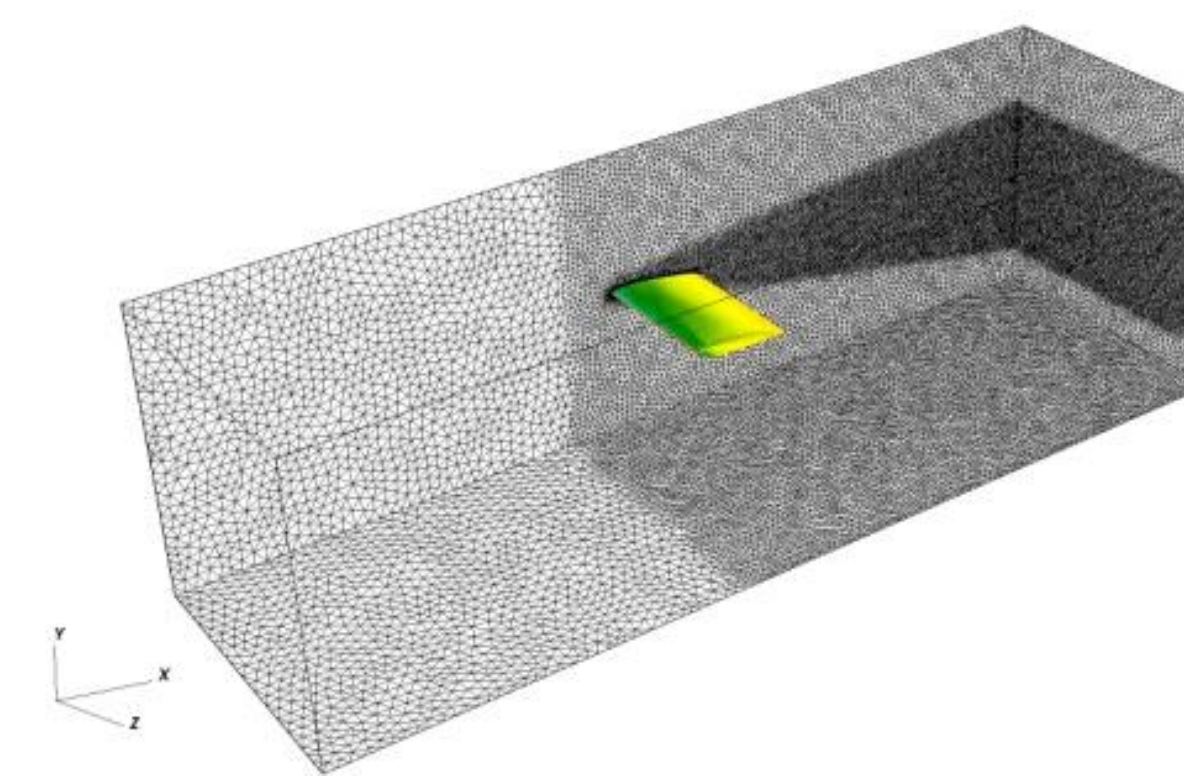
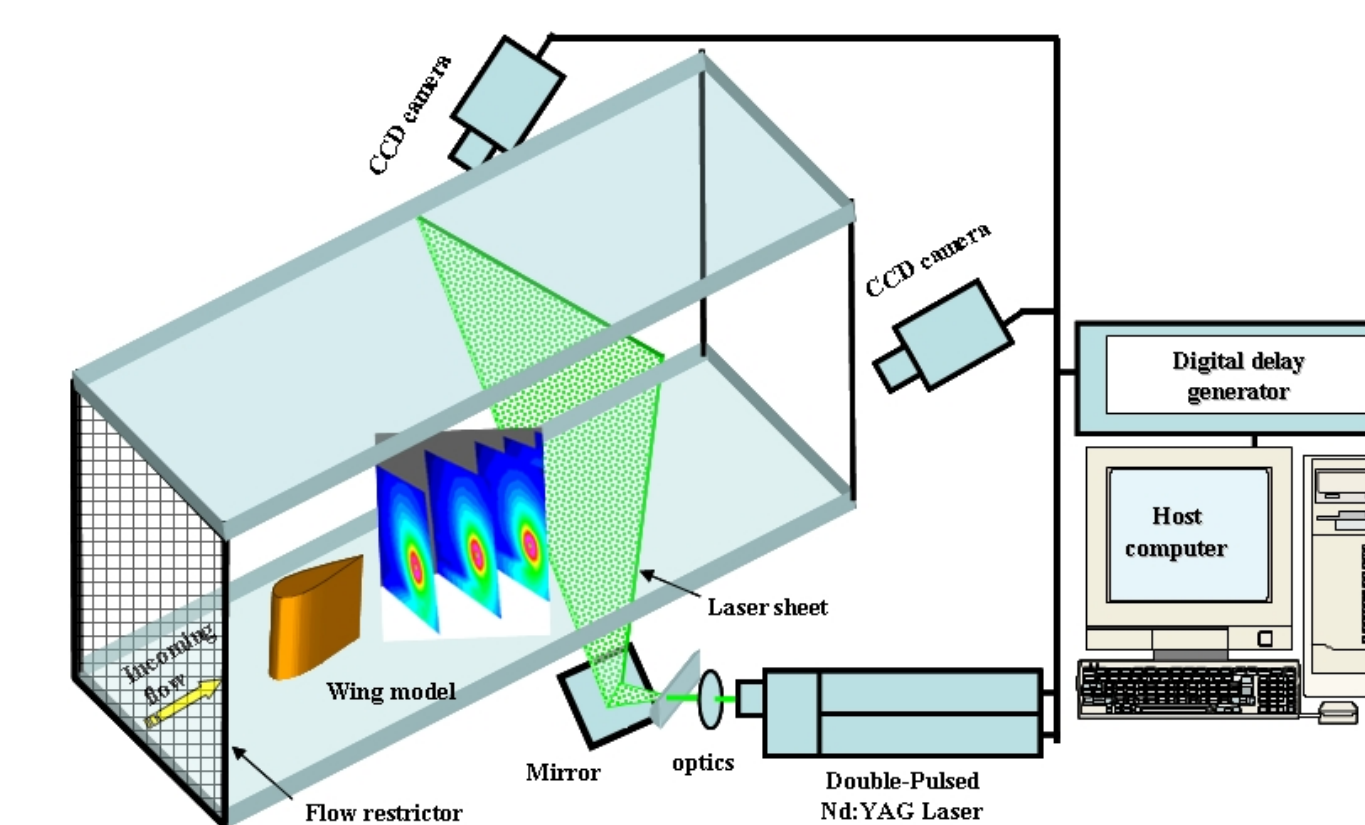
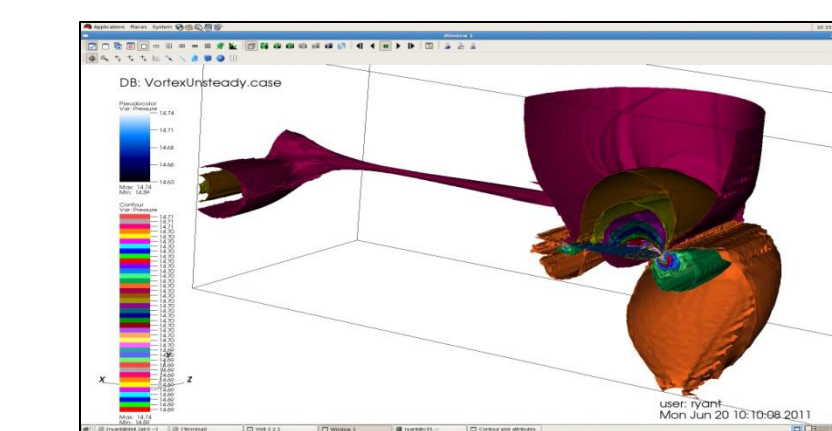
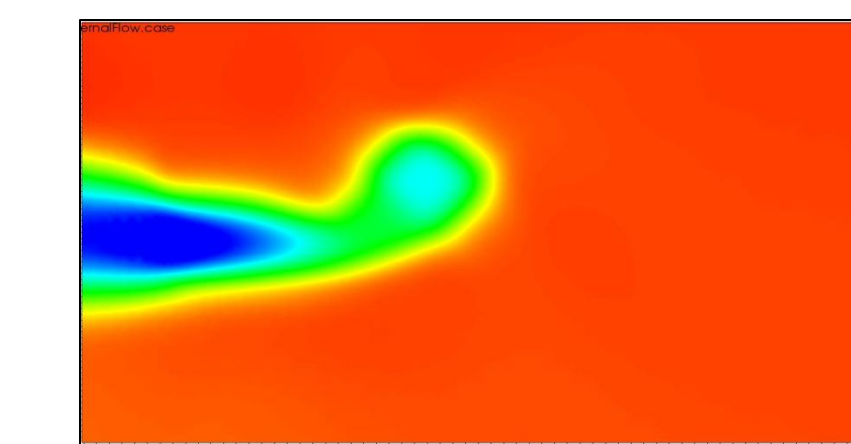


Figure 1 – Visual Representation of Wingtip Vortices (Ref 3)

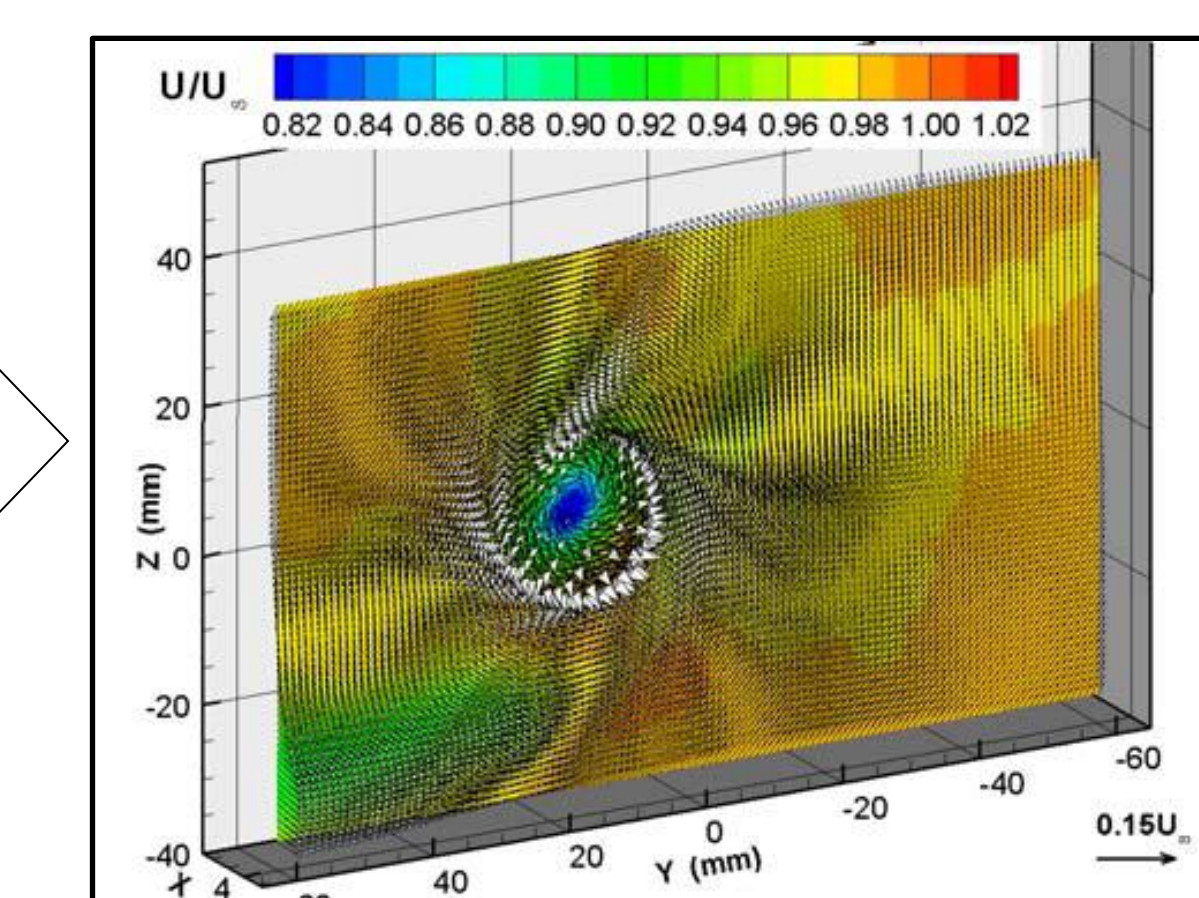
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Numerical results of simulations sent to visualization program *VisIt*



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## Legends

